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RELATION OF HUSK COVERING TO SMUT OF CORN EARS

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CONTENTS

	Page		Page
Introduction	1	Influence of environment on husk protection	4
Methods and materials	1	Conclusions	6
Genetic behavior of husk protection	2	Summary	6
Relation between husk covering and smutted ears	4	Literature cited	6

INTRODUCTION

Jones (*5*, *6*),[1] Hayes, and others (*3*), Garber and Quisenberry (*2*), and Immer and Christensen (*4*) have reported evidence on the genetic behavior in corn of resistance to smut (*Ustilago zeae*), and most corn breeders give consideration to the matter of selection for resistance to this disease. In breeding for resistance it is desirable to know what plant characters, if any, are responsible for resistance. With this definite knowledge, plants possessing such characters may be selected by sight or on the basis of some positive test with the assurance that the desired end will be reached as the selected characters are fixed.

Collins and Kempton (*1*) have shown negative correlation between corn ear-worm (*Heliothis obsoleta* Fab.) damage and distance from the tip of the husks to the tip of the ear. Kyle (*7*) has shown that husks that tightly inclose the ears protect them from rice or "black" weevils (*Calendra oryzae* L.). This bulletin deals with the relationships between husk coverings and ear smut of corn.

METHODS AND MATERIALS

The data were obtained in 1926 at the Arlington Experiment Farm, Rosslyn, Va., on 21 F_1 crosses between 7 self-fertilized corn lines, 2 of which (A and B) were from Garrick corn, 2 (C and D) from Boone County White, and 3 (E, F, and G) from Cuban Yellow. The Garrick lines had been selfed for 10 years, the Boone County White lines for 6 years, and the Cuban Yellow lines for 7 years before making the

[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 6.

crosses for this experiment. These particular lines were chosen because preliminary trials indicated that they consistently represent extremes for the characters to be studied. Their peculiarities will become apparent with a study of the data. With one exception each cross was grown in 60 single rows of about 10 plants each. The distribution of the rows of a cross was made systematically. The self-fertilized lines are designated by index letters, and the crosses are indicated by the two letters representing the parent lines involved.

Natural infection was relied upon to produce the disease. It is believed that there was abundant opportunity for plants to become smutted, as 90 to 100 per cent of the plants of susceptible strains grown in plots adjacent to these experiments were diseased.

Lateral buds, or potential ear shoots, usually appear at a number of the culm nodes of the corn plant and sometimes at nodes of the ear shanks or stems by which ears are attached to the culms. In the experiments reported here it was observed that most if not all of the nodal smut originated in these shoots, which is in agreement with the observations of Potter and Melchers (*8*). In these experiments a greater proportion of the shoots bore grain in some crosses than in others, variable growing conditions being responsible for considerable fluctuation in this regard. Varying with each cross, therefore, those shoots from nodes that normally bore grain were classed as "primary shoots" and those from nodes that normally did not bear grain were classed as "secondary shoots." Occasionally, for unusual reasons, a shoot classed as primary had no grain and one classed as secondary had a slight quantity.

The husks were examined on the plants before they had dried, and the number of ears completely inclosed in husks and the number exposed through openings in or between the husks were recorded. The first class is termed "husk protected" and the last is termed "exposed." Birds tore the tips of many of the thinner husk coverings, but preliminary examinations revealed no evidence that smutting followed this damage, and it therefore was disregarded.

Corn ear-worms (*Heliothis obsoleta* Fab.) very commonly entered husks that otherwise completely covered the ears. As the tissues concerned usually had passed the smut-susceptible stage before the worm damage occurred, the holes made by the insects in most cases were not a factor in permitting or preventing infection. A very few primary shoots were damaged by ear worms at an earlier stage of development while the tissues were still susceptible to smut. This damage was of such nature and effect that these shoots were classed as exposed, although all other cases of ear-worm damage were ignored in classifying the material for husk protection.

GENETIC BEHAVIOR OF HUSK PROTECTION

Table 1 shows the total number of ears produced, the total number of husk-protected ears, the number of husk-protected ears per 1,000 ears produced, the total number of smutted ears, and the number of smutted ears per 1,000 plants in each cross and in the average of the crosses of each selfed line with the other six lines.

The table shows that in ascending order the average number of husk-protected ears per 1,000 ears in the crosses of each selfed line with each of the other six in the experiment were 600, 609, 712, 748, 847, 923, and 946 for the lines C, A, D, B, E, F, and G, respectively.

The range in husk protection, as measured by the differences between the minimum and maximum numbers of husk-protected ears per 1,000 ears, among the crosses of each of the parent lines in the same order is 779, 741, 540, 537, 390, 141, and 83 ears. This is in descending order for magnitude of range. The range in husk protection among the different crosses of a given line in this experiment tended to be inversely proportional to the average number of husk-protected ears per 1,000 in those crosses as a group.

TABLE 1.—*Relation between the proportions of husk-protected ears and smutted ears in different F_1 crosses between indicated selfed lines of corn, at Arlington Experiment Farm in 1926*

Parent line	Items of comparison	Number of ears produced by parent line—							Total	Average
		A	B	C	D	E	F	G		
A	Total ears	-------	934	656	1,034	842	723	243	4,432	-------
	Husk-protected ears:									
	Total	-------	628	119	612	505	613	224	2,701	-------
	Per 1,000 ears	-------	672	181	592	600	848	922	-------	609
	Smutted ears:									
	Total	-------	16	38	14	43	6	1	118	-------
	Per 1,000 plants	-------	30	66	25	80	11	6	-------	40
B	Total ears	934	-------	563	647	568	563	649	3,924	-------
	Husk-protected ears:									
	Total	628	-------	235	410	511	537	614	2,935	-------
	Per 1,000 ears	672	-------	417	634	900	954	946	-------	748
	Smutted ears:									
	Total	16	-------	19	11	2	8	7	63	-------
	Per 1,000 plants	30	-------	34	19	4	14	12	-------	19
C	Total ears	656	563	-------	650	516	552	548	3,485	-------
	Husk-protected ears:									
	Total	119	235	-------	243	460	508	526	2,091	-------
	Per 1,000 ears	181	417	-------	374	891	920	960	-------	600
	Smutted ears:									
	Total	38	19	-------	22	19	10	2	110	-------
	Per 1,000 plants	66	34	-------	39	35	18	4	-------	33
D	Total ears	1,034	647	650	-------	686	673	723	4,413	-------
	Husk-protected ears:									
	Total	612	410	243	-------	604	615	656	3,140	-------
	Per 1,000 ears	592	634	374	-------	880	914	907	-------	712
	Smutted ears:									
	Total	14	11	22	-------	2	3	0	52	-------
	Per 1,000 plants	25	19	39	-------	4	5	0	-------	15
E	Total ears	842	568	516	686	-------	439	487	3,538	-------
	Husk-protected ears:									
	Total	505	511	460	604	-------	434	482	2,996	-------
	Per 1,000 ears	600	900	891	880	-------	989	990	-------	847
	Smutted ears:									
	Total	43	2	19	2	-------	3	1	70	-------
	Per 1,000 plants	80	4	35	4	-------	7	2	-------	23
F	Total ears	723	563	552	673	439	-------	463	3,413	-------
	Husk-protected ears:									
	Total	613	537	508	615	434	-------	443	3,150	-------
	Per 1,000 ears	848	954	920	914	989	-------	957	-------	923
	Smutted ears:									
	Total	6	8	10	3	3	-------	1	31	-------
	Per 1,000 plants	11	14	18	5	7	-------	2	-------	10
G	Total ears	243	649	548	723	487	463	-------	3,113	-------
	Husk-protected ears:									
	Total	224	614	526	656	482	443	-------	2,945	-------
	Per 1,000 ears	922	946	960	907	990	957	-------	-------	946
	Smutted ears:									
	Total	1	7	2	0	1	1	-------	12	-------
	Per 1,000 plants	6	12	4	0	2	2	-------	-------	4

When a line with extremely long husks, line G for example, was crossed with each of the other six, the number of protected ears per 1,000 was much the same in the different crosses, having a range of only 83 ears. When line C with extremely poor husk protection was crossed with each of the other six, the number of protected ears per 1,000 in the different crosses differed widely, showing a range of 779.

In the cross CG, representing lines for poor and good husk protection, the number of husk-protected ears was 960 per 1,000, which number is exceeded by only two other crosses.

The data might be taken to suggest that the factors for husk protection are dominant. Husk protection is dependent upon the length, thickness, tightness, and texture of the husks, also upon the size of the ears that the husks are to protect. Ear size varies widely with the growing conditions, as will be shown later. It seems more probable that there was intermediate inheritance of the husk complex and that line G carried factors which, combined with those of any of the other lines, caused the development of intermediate F_1 husks sufficient to protect most of the ears within the range in ear size which occurred. On the other hand line C contributed relatively little to the genetic complex controlling protection, as is evidenced by the cross AC with only 181 per 1,000 of its ears protected. Husk protection of a cross involving line C depended largely upon the other parent and tended to vary accordingly. Plate 1, A and B, and Plate 2, A and B, illustrate characteristic husk coverings.

RELATION BETWEEN HUSK COVERING AND SMUTTED EARS

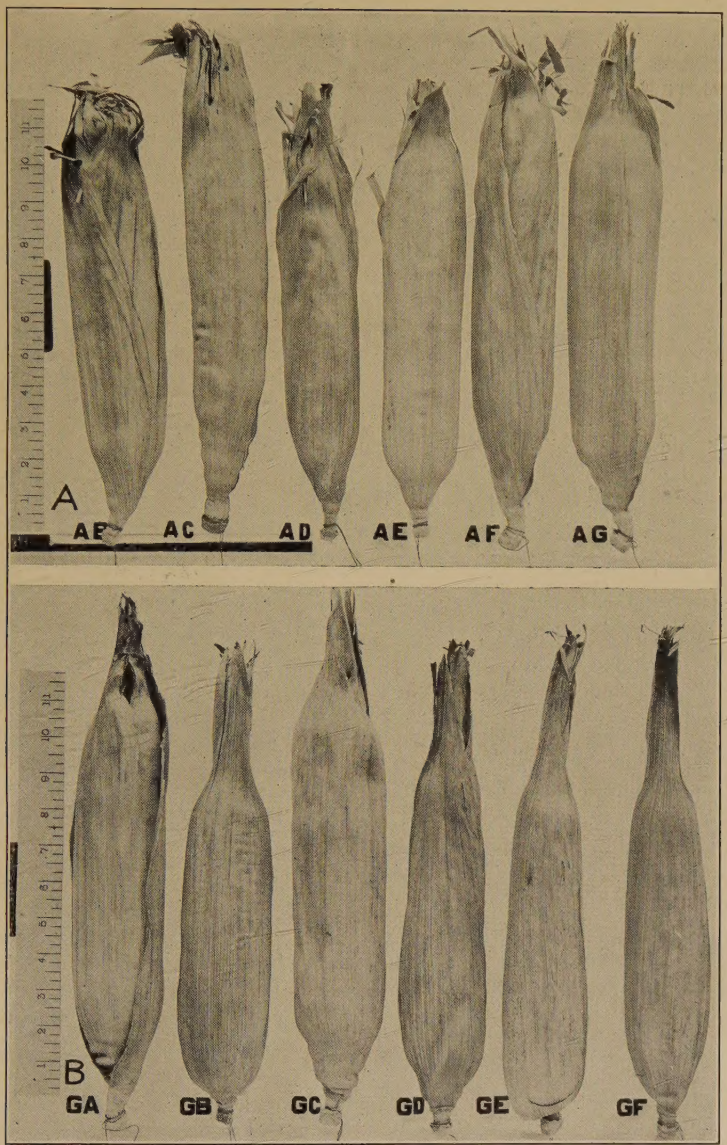
Of the 13,159 ears grown from all of the crosses, 9,979 were in the husk-protected class, and none of these were smutted. On the other hand, 228, or 72 per 1,000 of the 3,180 ears in the exposed class, were smutted.

As the ears always were free from smut when tightly inclosed by husks, it is evident that the number of smutted ears must be inversely proportional to the number of husk-protected ears and that any departure from this tendency must be due to escape or to resistance not correlated with husk protection.

As shown in Table 1, the crosses involving lines F and G had the largest proportion of protected ears, and of these two groups an average of only 7 ears per 1,000 were smutted. The crosses involving lines B, D, and E had an intermediate proportion of protected ears, and of their combined crop 19 ears per 1,000 were smutted. The crosses involving lines A and C had the smallest proportion of protected ears, and 36.5 ears per 1,000 of their total number were smutted. The crosses with the best husk protection, the G crosses, produced approximately one-eighth as many smutted ears as the crosses with the poorest husk protection, the C crosses.

INFLUENCE OF ENVIRONMENT ON HUSK PROTECTION

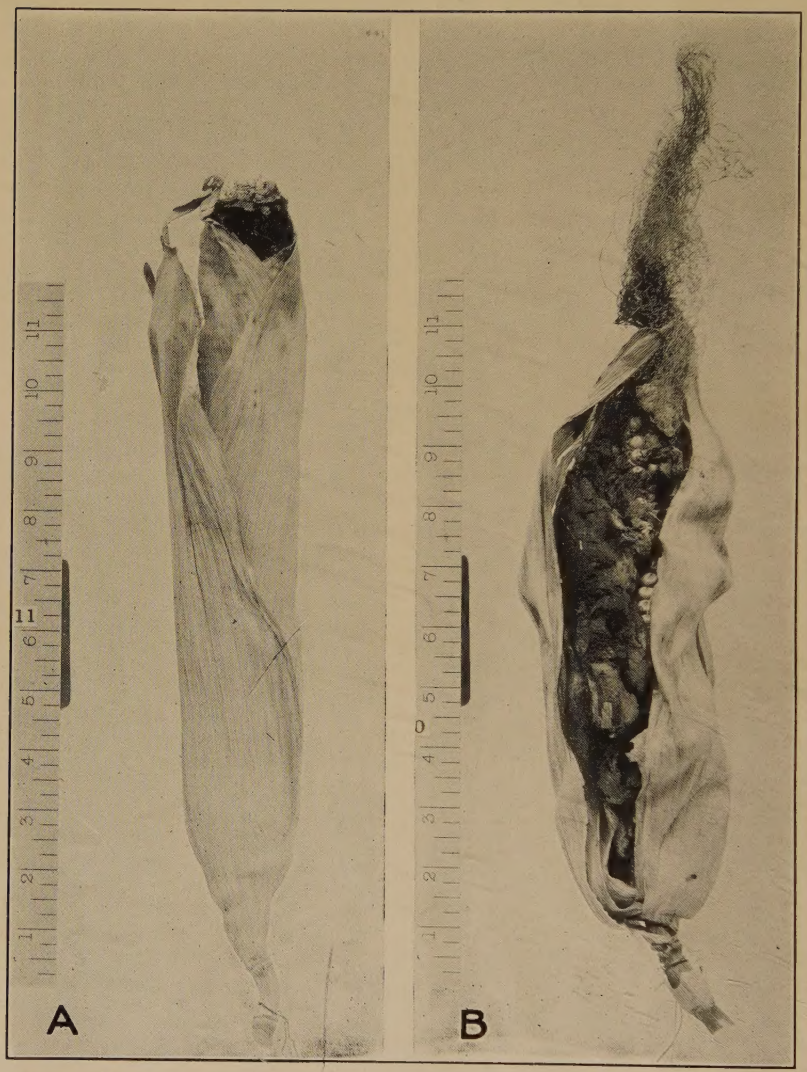
Most of the soil of the experimental plots was a silt loam, but certain irregular spots were very sandy. There was a deficiency of rainfall during a period of some weeks, ending near the close of the pollinating period for the latest cross. The size of culms and ears in most of the crosses was obviously less on the sandy spots than on the silt-loam soil. It is probable that husk development also was correspondingly less on the sand and that husk growth was nearly or quite complete at the close of the drought. Rains were frequent after the drought was broken, and the water supply was ample for subsequent growth on both classes of soil. Ear development in the later crosses was more nearly alike on the two soils than was husk development, husk development being completed earlier in the life



SOME TYPICAL HUSK COVERINGS

A.—Husks on a representative ear of the cross between line A and each of the other six lines in the experiments. Line A is extreme for short thin husks. The ears chosen to represent the crosses were sufficiently covered to prevent smutting, but the relative thinness of the husks is indicated by relative proportions of shredding by birds. Crosses AB, AC, AD, and AF show the shredding, AE and AG remaining fairly intact.

B.—Husks on representative ears of the cross between line G and each of the other six lines in the experiments. Line G was an extreme for long tight husks, and its crosses had the highest percentage of husk-protected ears. The husk representing cross GA is typical for length and compactness of covering, but the split near the tip rarely occurs and shows how an otherwise good covering may sometimes permit infection of the ear. All of the coverings were too thick and tough for the birds to tear, and especially in crosses GB, GD, GE, and GF they remained as a tightly inclosing sheath when dry.



CLASSES OF HUSKS THAT MOST COMMONLY PERMIT SMUTTING OF THE OVULES

A.—Husks too short to cover the tip of the ear, and smut galls have developed on the exposed ovules. A part of the smut growth was removed to show the cob.

B.—A thin loose husk that permitted ovules of the poorly filled cob to become infected by smut.

cycle and on the sandy soil being limited by the drought. The relatively large ears and small husk of the late crosses resulted in a higher percentage of unprotected ears on the sandy soil.

The earliest cross completed its silking about two weeks before the latest. The ears of this cross, being affected longer by drought during their growing period, were smaller than those of later crosses. The ears of cross CD were most seriously affected in this way. The husk development of this cross was lessened by the drought, but the ears were relatively so much more affected that a proportionately smaller number of them outgrew their husks on the sandy soil than on the heavier soil.

Comparable data were obtained from seven crosses on each of the two classes of soil. These are shown in Table 2. The comparisons are made between crosses differing by one parent and in relative length of the period from planting to silking, the duration of the period being indicated by the terms short, midlength, and long.

Table 2 shows the total and average weight of ears, the total number of ears produced, the number of husk-protected ears, and the percentage of husk-protected ears for silt and sandy soil, also the average weight and percentage of husk protection of ears on sandy soil expressed as a percentage of that on silt soil.

TABLE 2.—*Effect of soil variations in modifying the percentage of husk-protected ears by altering the relative development of the husks and ears in different F_1 corn crosses at Arlington Experiment Farm in 1926*

Comparison and cross	Period from planting to silking	Ears produced on silt soil					Ears produced on sandy soil					Ears on sandy soil compared as a percentage of those on silt soil	
		Weight (pounds)		Number		Percentage protected	Weight (pounds)		Number		Percentage protected		
		Total	Average	Total	Protected		Total	Average	Total	Protected		Average weight	Protected
1 CD	Short	158	0.554	285	102	35.8	32	0.299	107	48	44.9	54.0	125.4
1 AD	Midlength	219	.372	588	439	74.7	76	.289	263	91	34.6	77.7	46.3
2 DF	do	140	.422	332	308	92.8	38	.311	122	107	87.7	73.7	94.5
2 BF	Long	149	.536	278	268	96.4	54	.466	116	98	84.5	86.9	87.7
3 DG	Short	145	.411	353	310	87.8	45	.296	152	138	90.8	72.0	103.4
3 BG	Midlength	159	.566	281	262	93.2	64	.418	153	141	92.2	73.9	98.9
3 AG	Long	106	.387	274	242	88.3	75	.389	193	149	77.2	100.5	87.4

Referring to the last two columns of Table 2, the sandy soil produced lighter ears than the silt soil in all except the long-period cross AG, and the relative average weight of these ears tended to be directly proportional to the length of the growing period. This soil also produced relatively fewer husk-protected ears than the silt in all except the short-period crosses CD and DG, and the relative proportion of these ears tended to be indirectly proportional to the length of the growing period. Comparing the data of the two columns, the relative average weights of ears and the relative percentage of husk-protected ears tended to be inversely proportional in each comparison.

Crosses AD and DF required about the same period from planting to silking, and the short-husk line D was represented in both. To this extent they were comparable. Line A contributed relatively little husk protection to AD, and line F contributed relatively much

husk protection to DF. Compared with the planting on silt soil, cross AD produced 537 and cross DF produced 55 more exposed ears per 1,000 when planted on sandy soil. The influence of the environment upon husk protection was marked in the combination between two lines with poor husk protection and was only slight in the combination between one line with poor and one with good husk protection. In the experiment as a whole, the crosses EF, EG, and FG, having the best average husk protection (Table 1), produced only 11, 10, and 43 exposed ears per 1,000, respectively. In these crosses exposures usually were due to exceptionally early ear-worm attack, or to the husks splitting over the sides of the ears, and not to loose husks or to ears growing through the end of the husk covers. Accordingly, exposure of ears in the best husk-protected crosses were affected scarcely at all by climatic or soil differences involved in these experiments.

CONCLUSIONS

The foregoing data indicate that strains of corn obtained by selection within self-fertilized lines differ widely in their ability to produce, in their crosses with other selfed lines, husks that will tightly inclose the ears. The data show that in these experiments there was a negative correlation between the number of husk-protected ears and the number of smutted ears, and that such protection was a factor in determining the relative resistance to ear smut of the crosses involved in these experiments.

SUMMARY

Seven self-fertilized corn lines with established differences in husk protection were represented in the experiments here reported by crosses resulting from all possible combinations of the seven.

It seems probable that intermediate inheritance of the husk complex in combination with variable ear size gave the resulting husk protection in the different crosses.

All of the ears tightly inclosed by husks were smut free. The crosses involving line G were the best husk-protected group and produced approximately one-eighth as many smutted ears as the group of crosses involving line C, which were poorest in husk protection.

The relative sizes of husks and ears varied with environment, causing fluctuation in the proportion of husk-protected ears for different conditions. Environmental effect was slight, however, in crosses that had the greatest average proportion of husks to size of ears.

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